NAVAL AVIATION SYSTEMS

PRESENTATION TO:

Joint Technology Exchange Group (JTEG)

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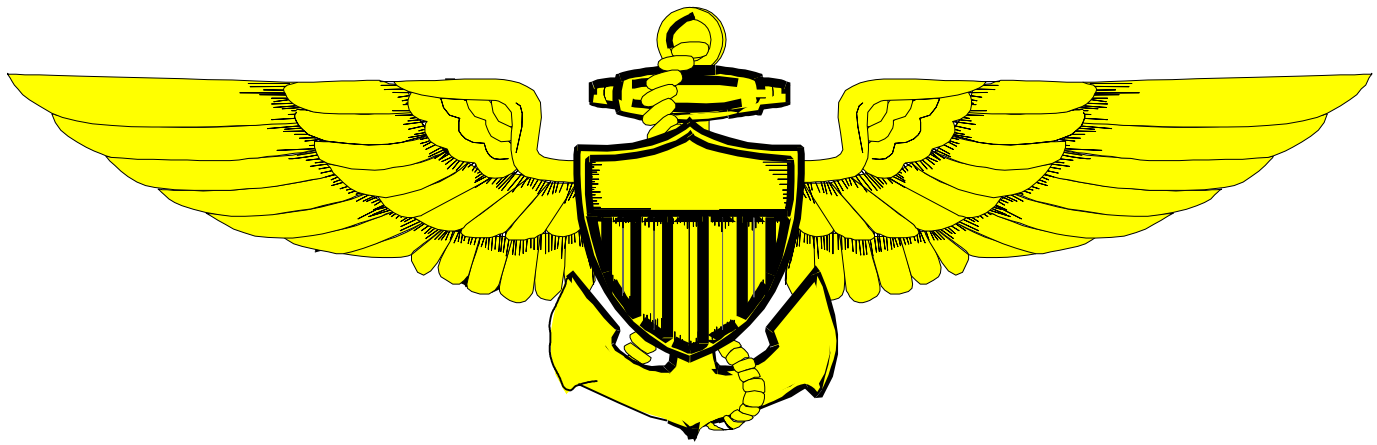
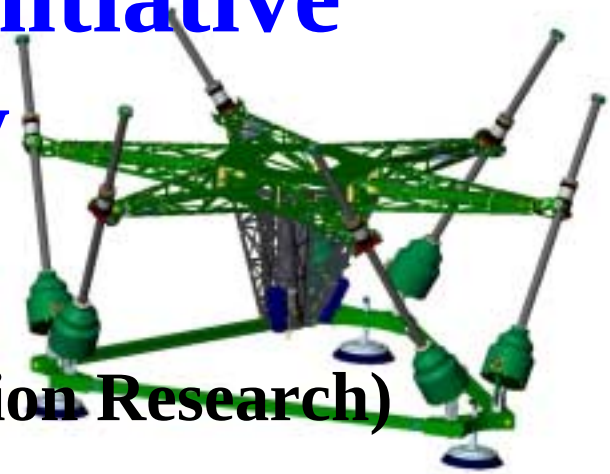
Automated Scarfing Initiative

- **NCMS Issue (Draft Concept Paper Submitted)**
  - **Goals**
    - **Improve Repeatability**
    - **Reduce Material Usage**
    - **Reduce Repair Fallout**
    - **Add throughput and accuracy improvement features**
  - **Scope**
    - **Follow-up Work to STARC (Scarfing Tool for Automated Repair of Composites) Initiative**
    - **Industrial (DEPOT) Testing**
    - **On or Near Aircraft Testing (?)**



Origin of the Effort

Automated Scarfing Initiative Project History



- **STARC-**
  - **Navy SBIR (Small Business Innovation Research) with PushCorp, Inc.**
    - **Problem - Producing Consistent Scarfs for Composite Navy Aircraft**
    - **Solution - Build An Automated Device (STARC)**
  - **Equipment Development - Completed**
  - **Manufacturer's Demonstration Testing - Completed**
  - **Shipment to NADEP Cherry Point - Estimates being compiled for funding**

Project Accomplishments

- **Developed a lightweight, portable, general-purpose manipulator with sufficient stiffness to perform machining operations.**

- **Developed an extremely user-friendly graphical user interface that allows most anyone to produce high-quality scarfs with minimal training.**

Project Accomplishments (cont)

- **Developed a Differential Evolution genetic algorithm for calculating the forward kinematics of a general Stewart Platform manipulator.**

- **Developed a automatic non-contact surface measurement system capable of mapping a complex contoured composite surface with minimal user intervention.**

Project Accomplishments (cont)

- **Developed B-Spline surface techniques to produce cutting tool paths for producing scarf geometry in complex contoured parts.**

- **Developed distributed, real-time, open-architecture robot control software capable of controlling most any manipulator configuration for which the kinematics can be calculated in a reasonable length of time.**

Possible Improvements

- **Improve manipulator stiffness**
- **Ease manipulator setup / tear-down for better portability**
- **Improve cut quality with higher-speed spindle motor**
- **Improve surface measurement system durability**
- **Dramatically reduce manipulator-to-controller cabling**

Possible Improvements (Cont)

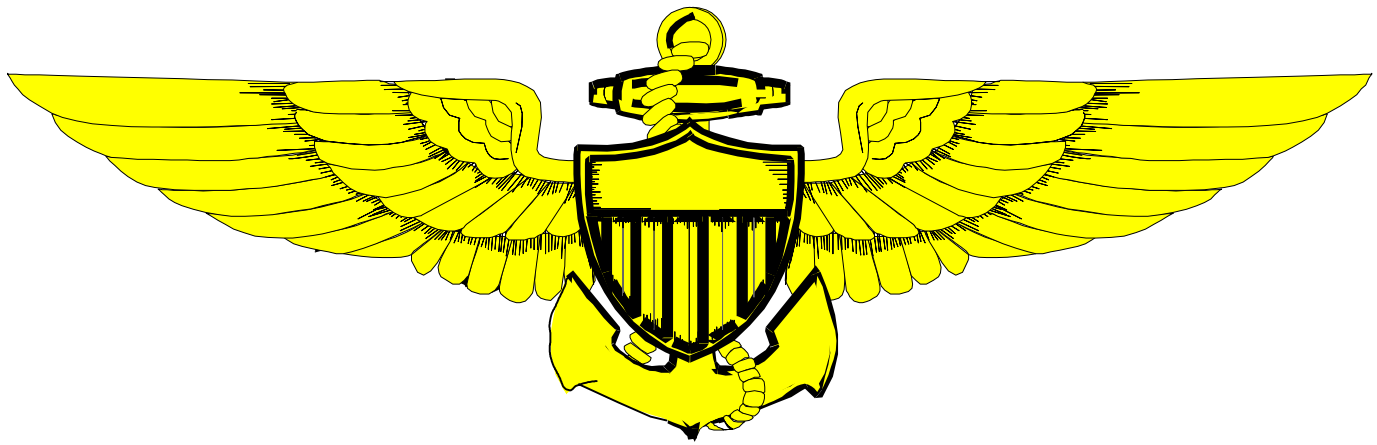
- **Improve controller packaging: dramatically reduce controller size**
- **Port controller software to a long-term maintainable real-time operating system**
- **Add software feature for arbitrarily shaped scarf profiles**
- **Add reversing algorithm to make repair “cake”**
- **Add software feature to be able to run standard RS-274 NC machine code**

Potential Applications

- **Specialized scarfing operations: wing leading edges.**
- **Polishing/repairing aircraft cockpit canopies.**
- **Removal/application of aircraft paint and/or low-observable coatings.**
- **Drilling fastener hole patterns for repairs.**
- **Drilling out existing fasteners.**
- **Routing skin panel equipment access holes.**

Potential Applications

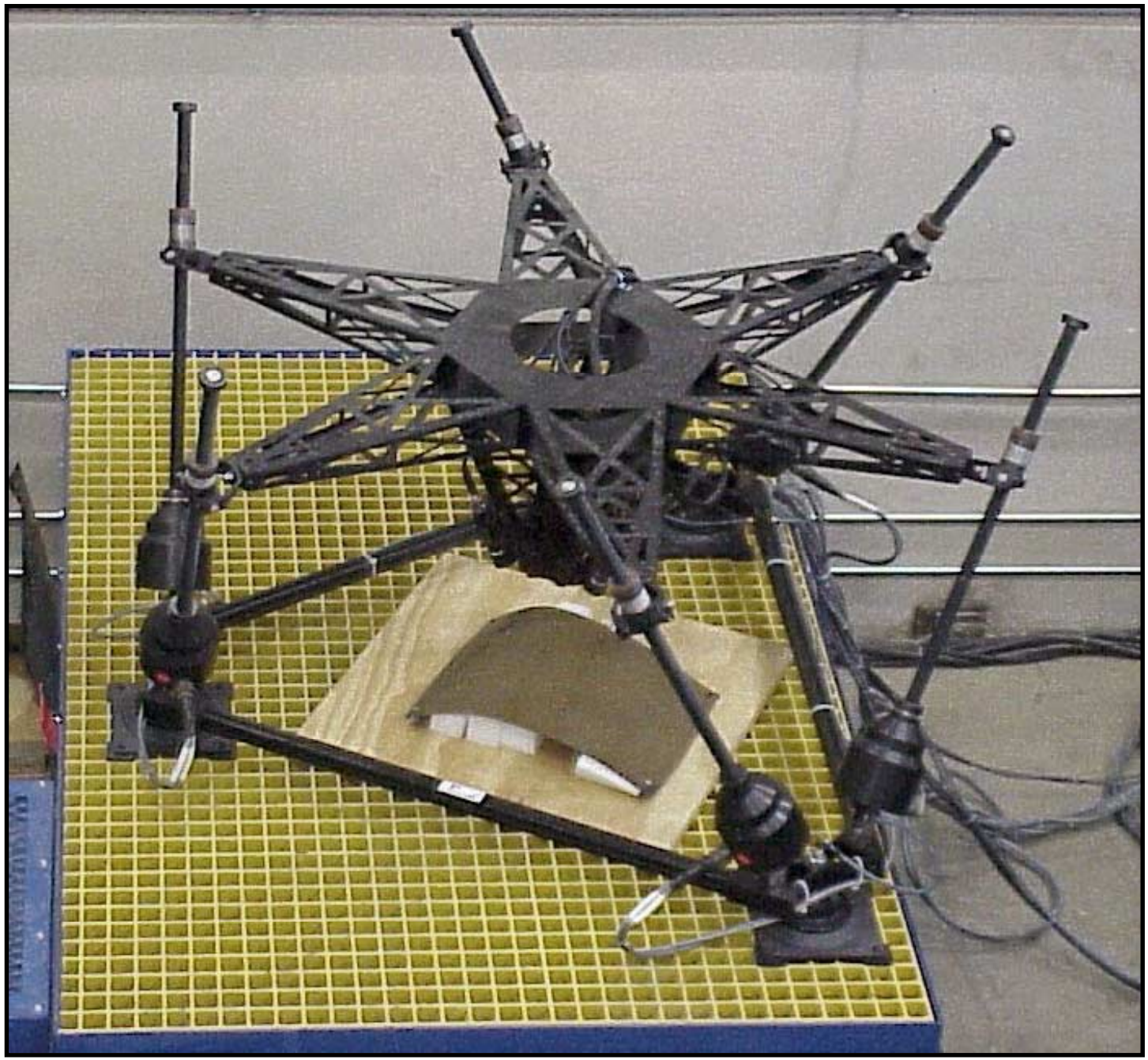
- **Sanding/grinding operations to smooth composite repairs.**
- **Measuring and verifying surface contours of finished composite repairs using original manufacture's CAD data.**
- **Larger unit heavy lifting operations, bomb loading etc.**
- **Other specialized manipulators using same controller**



Demonstration

Basic Operation

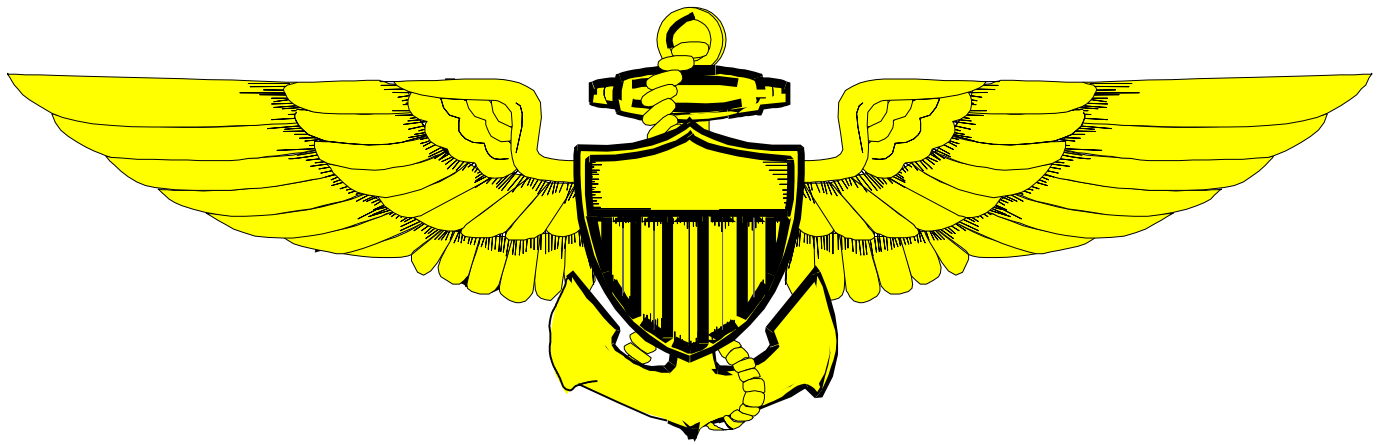
- Mount Manipulator to Surface
- Power Up and Home Manipulator
- Designate Scarf Center Point
- Input Scarf Parameters
- Scan Surface Profile
- Input Process Parameters
- Machine Scarf Profile



Scarfed Composite Part

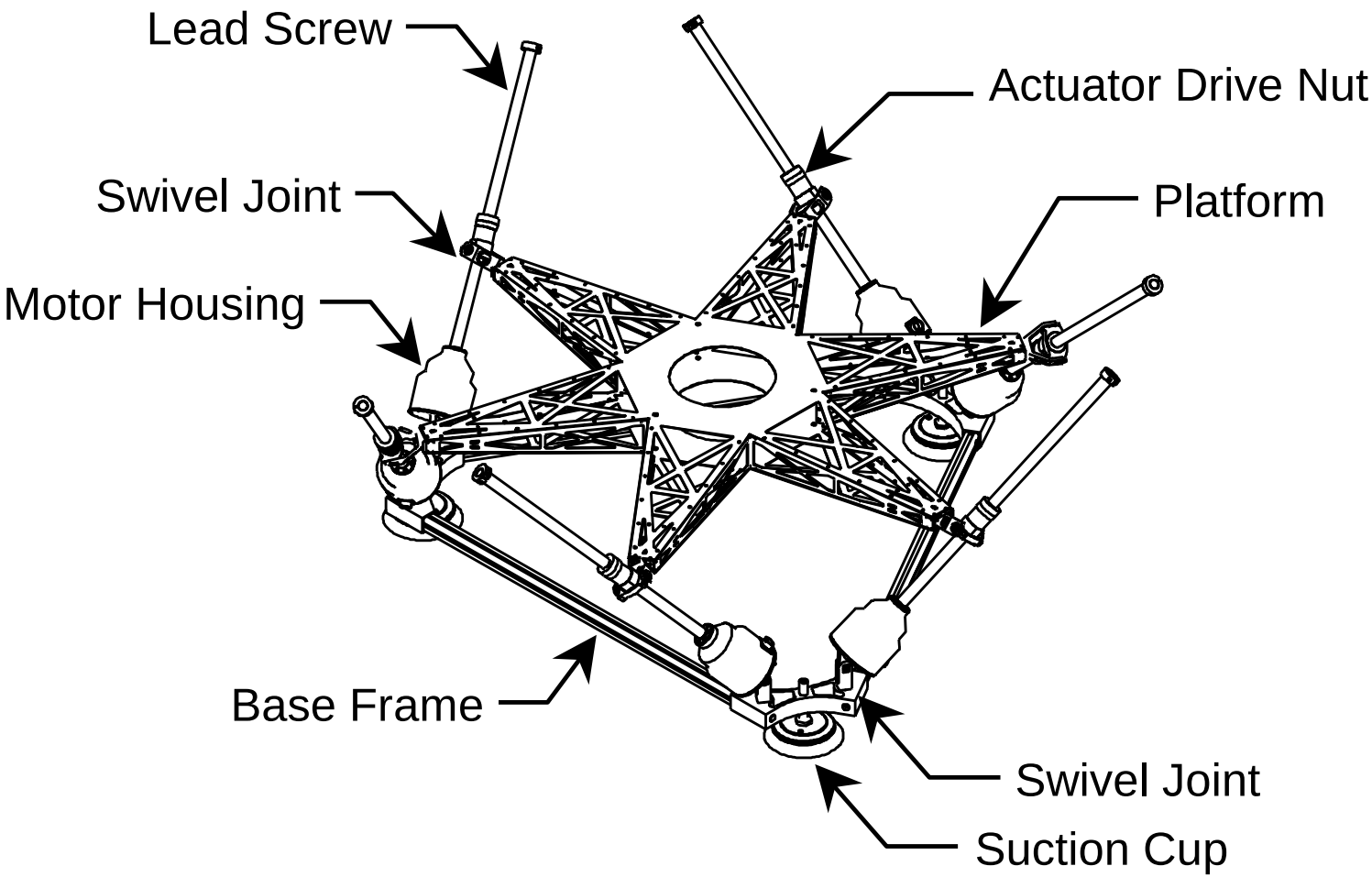
STARC In Action

starc-movie

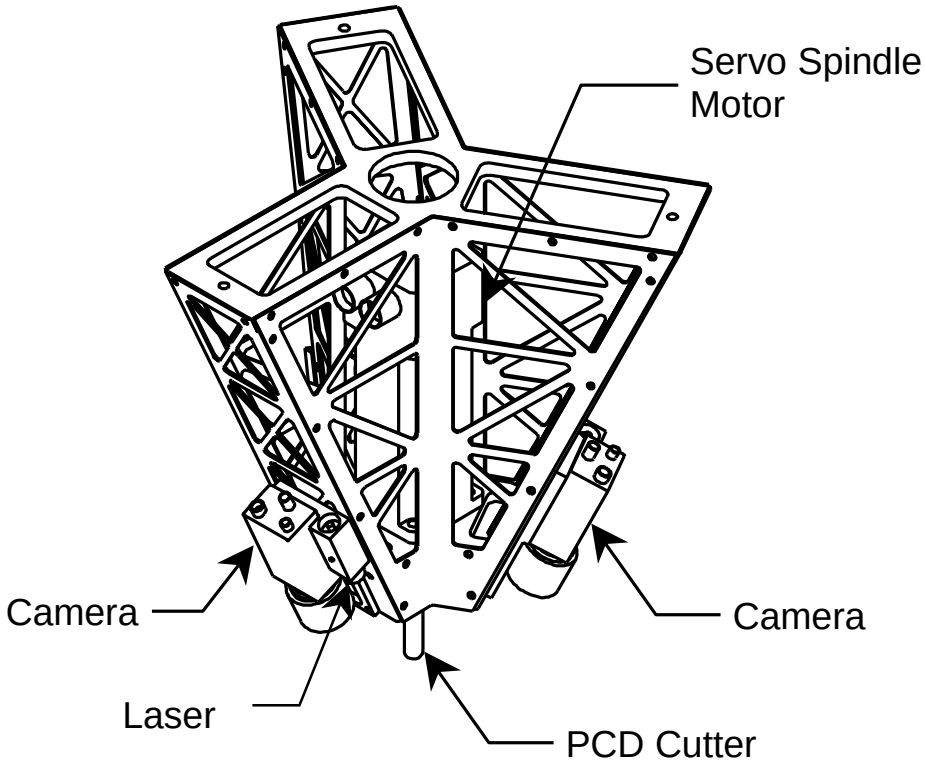


Components of the System

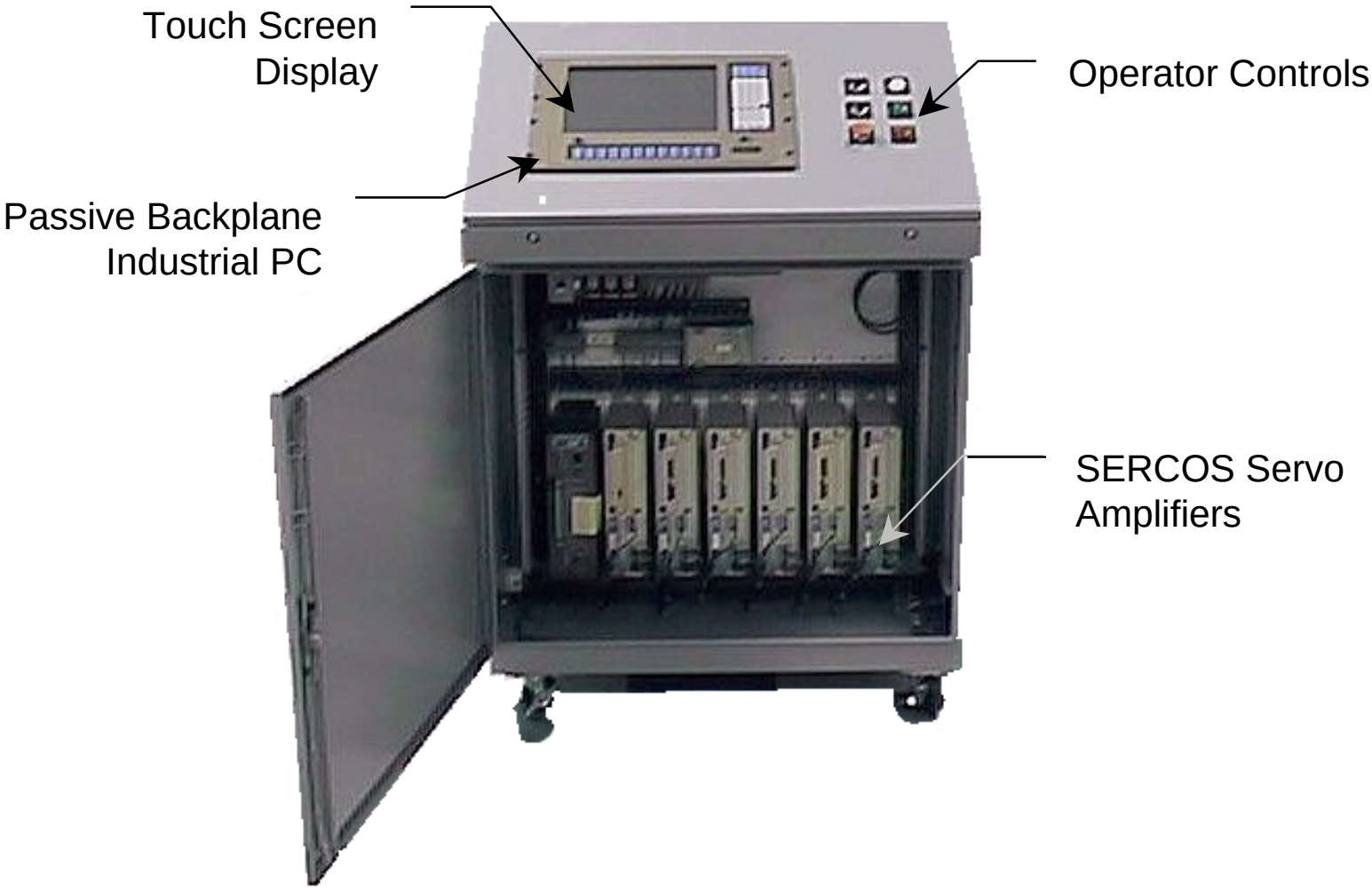
STARC Manipulator



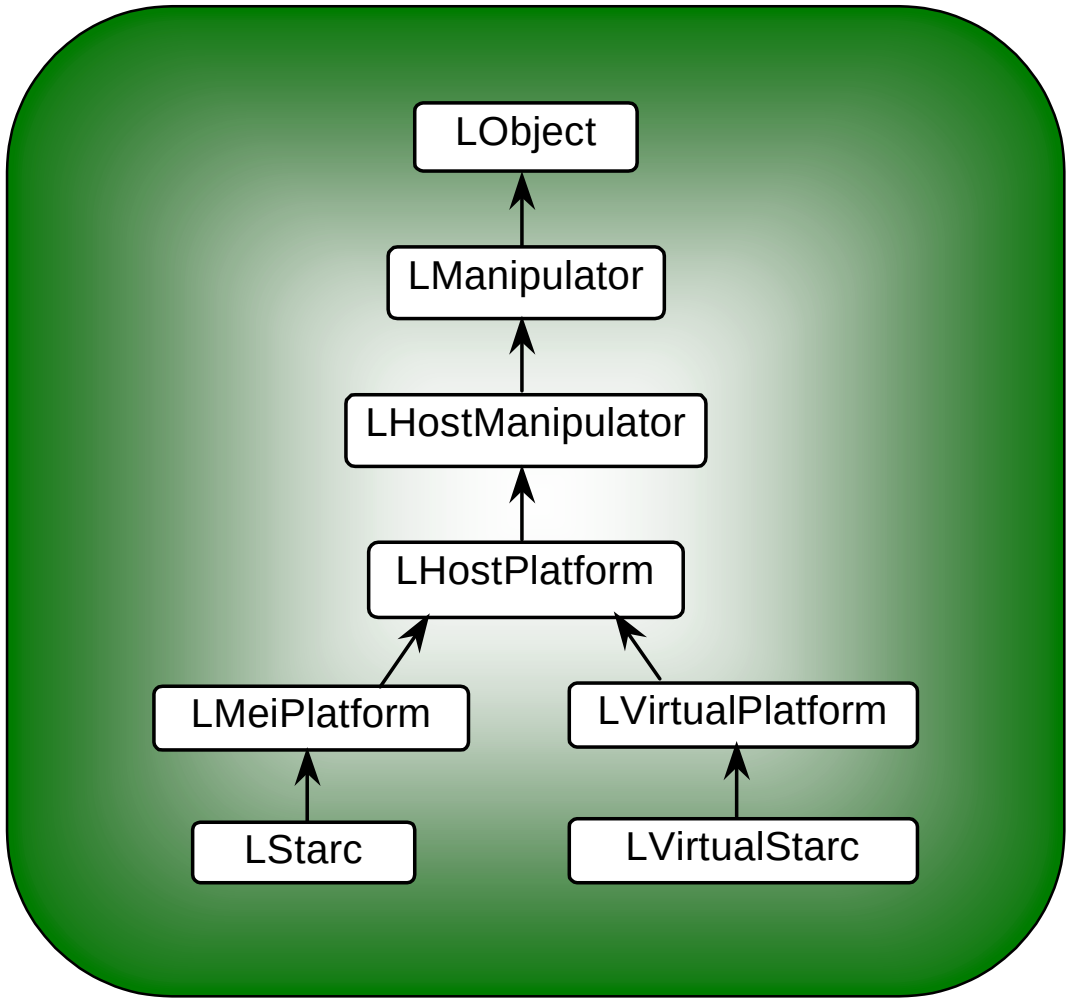
Scarfing Process Module



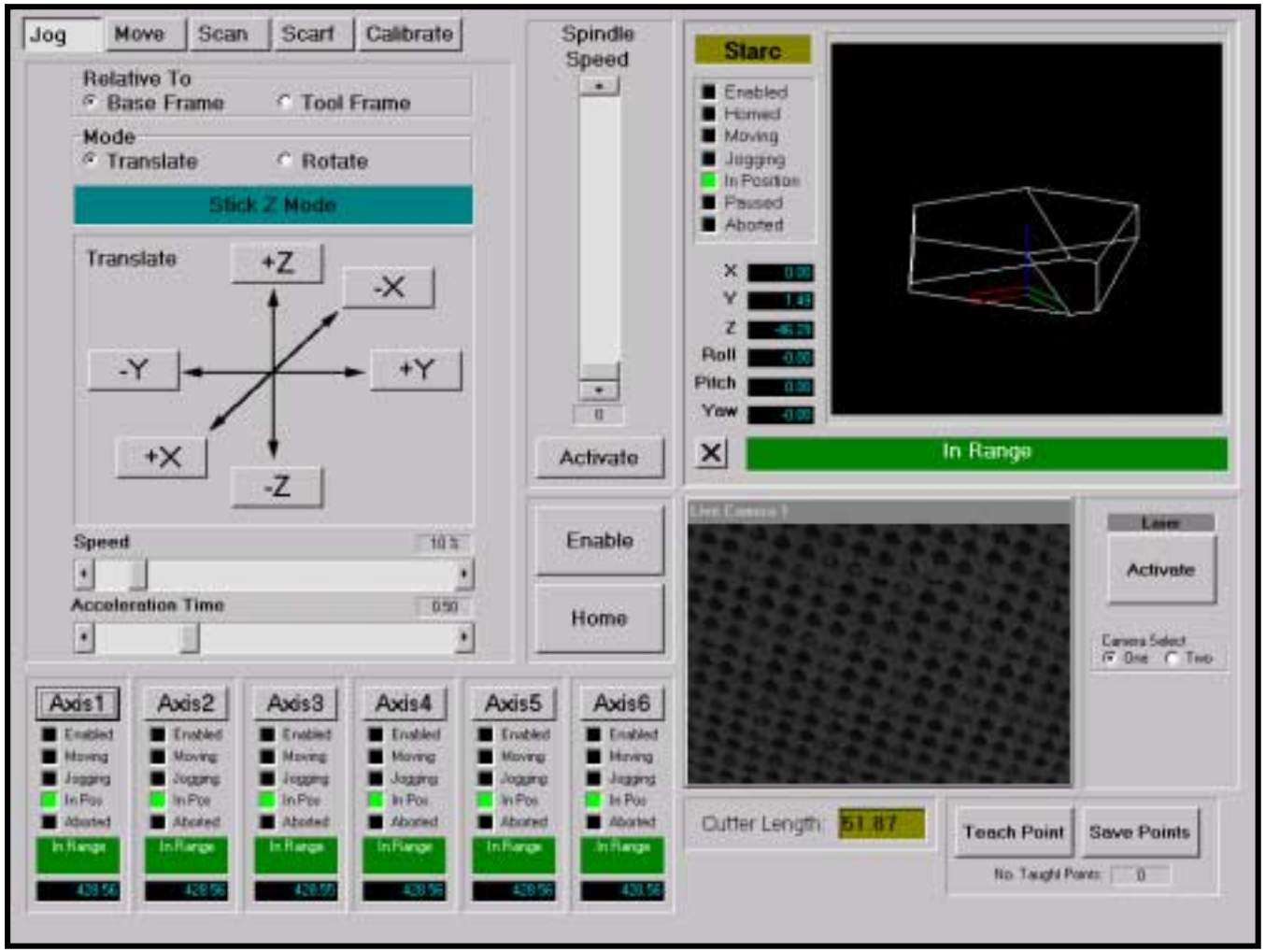
User Interface Controller

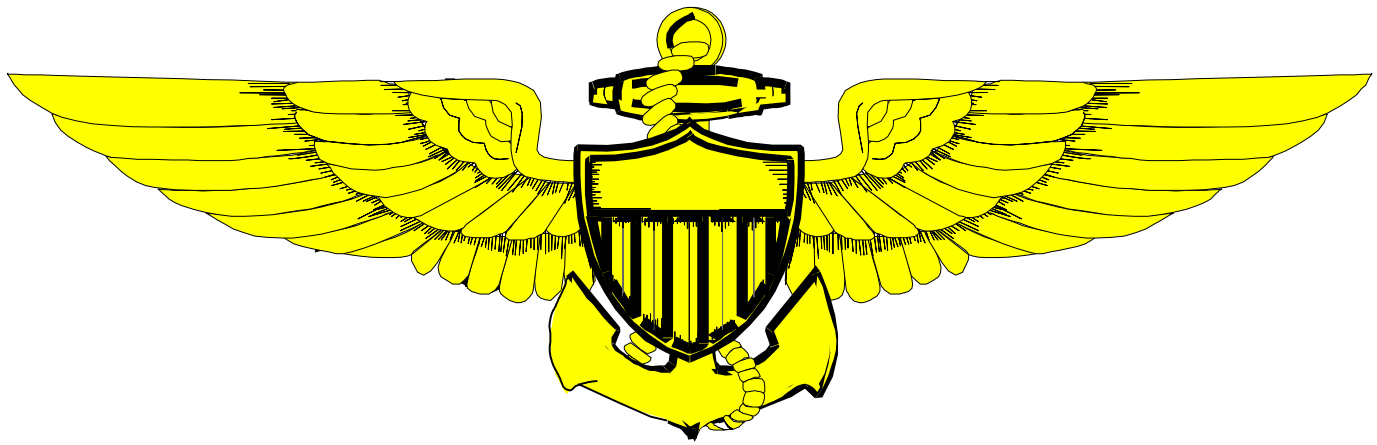


Object-Oriented Software Design



STARC User Interface





Background

Who is PushCorp?

- **Founders met at University of Texas, Arlington**
- **Incorporated in 1993**
- **Manufacturer of Active Force Control compliant tooling**
- **R & D: 2 to 3 new products every year**
- **Average 30% growth in sales per year**
- **Primary customers: Automotive, Tier 1 Automotive suppliers**

STARC Motivation

- **Reduce scrap and rework**
- **Reduce long-term medical problems**
- **Reduce time to produce scarf**
- **Reduce need for highly-specialized repair personnel**
- **Increase control and consistency of scarf repair geometry**

STARC Features

- A portable parallel link Stewart Platform manipulator and a separate controller connected via a interface cable.
- Aircraft attachment via vacuum cups, straps, or hard attachment points. Also free-standing mode.
- 36 inch diameter workspace on a planar surface. Workspace height of 20 inches.
- Surfaces with a minimum 6 inch radius curvature.
- Lightweight, servomotor driven, linear actuators.
- High stiffness to weight ratio with a total manipulator weight of 94 pounds.
- Payload capacity of 50 pounds.
- Maximum tool point speed of 5 inches per second in any direction.
- Servo spindle motor with 6200 RPM max. speed. (Higher speeds possible)
- Polycrystaline diamond end mill cutter.
- Easily accommodate a variety of process modules. (Including compliant force control tooling)
- Positional repeatability of +/- 0.005 inches (0.13 mm).
- Laser measurement system able to measure surface geometry within +/-0.015 inches (0.38 mm).
- Manipulator and controller can be separated by at 30 feet.
- Controller housed in a portable enclosure.
- Easy to operate graphical user interface.
- Controller able to generate tool paths to scan a surface, produce scarf profiles, jog tool , move to specific points in relative and absolute mode.
- Able to create and display 3D representations of contoured surfaces.

Potential Aircraft

- **V-22 Osprey** *Bell Helicopter / Boeing*

  Fuselage Sections, Empenage Sections, Wing Sections, Sponsons, Horizontal Stabilizers, Vertical Stabilizers, Rotor Blades
- **AV-8B Harrier** *McDonnell Douglas*

  Fuselage Sections, Wing Sections, Horizontal Stabilizers, Vertical Stabilizers
- **AH-1 Huey Cobra** *Bell Helicopter*

  Fuselage Sections, Rotor Blades
- **AH-64 Apache** *Hughes*

  Fuselage Sections, Rotor Blades
- **B-2 Spirit** *Northrop*

  Fuselage Sections, Wing Sections
- **F-22 Rapier** *Lockheed*

  Fuselage Sections, Wing Sections, Vertical Stabilizers, Horizontal Stabilizers
- **F-117 Nighthawk** *Lockheed*

  Fuselage Sections, Wing Sections, Vertical Stabilizers, Horizontal Stabilizers
- **C-17 Transport** *McDonnell Douglas*

  Engine Nacelles